

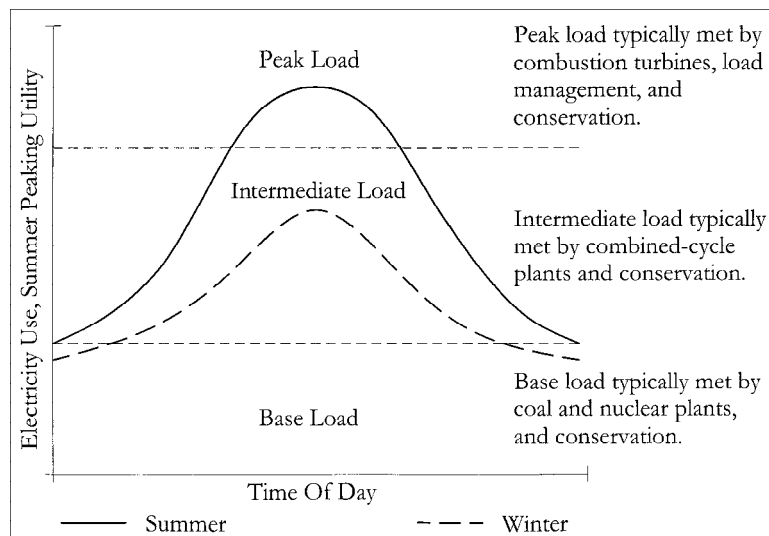
Electric Power Plants

This overview explains issues relevant to the production of electricity for the state of Wisconsin. It addresses basic power plant technologies and fuels, how the state's demand for reliable electricity is fulfilled, and the role the Public Service Commission (PSC) plays in ensuring electrical energy needs are met.

Electricity Use Patterns

Consumers' demand for electricity changes daily and seasonally. A manufacturing plant assembly line starts and stops throughout the day and week. Air conditioners are turned on and off seasonally. Figure 1 shows the total amount of electricity that electric customers demand at any given time of day. During peak times, the largest amount of electricity is needed ("peak load"), but a "base load" of electricity is needed year round. Because electricity cannot be stored, utilities must anticipate demand, even on the hottest summer day, and supply enough electricity to meet the demand. Utilities meet this demand with in-state power plants and by purchasing electricity from power plants in other states. The balancing of supply and demand is required in order to maintain a reliable electric system without a power interruption to the consumer.

Figure 1 Typical Electric Load Curve



Demand is the total amount of electricity that consumers use at a particular time and is measured in watts. One thousand watts is a kilowatt (kW) and one thousand kW is a megawatt (MW). Most home air conditioners require 2 kW to operate. One kW will turn on ten 100-watt light bulbs. A power plant rated at 1 MW will supply enough energy for 500 homes or ten thousand 100-watt bulbs simultaneously.

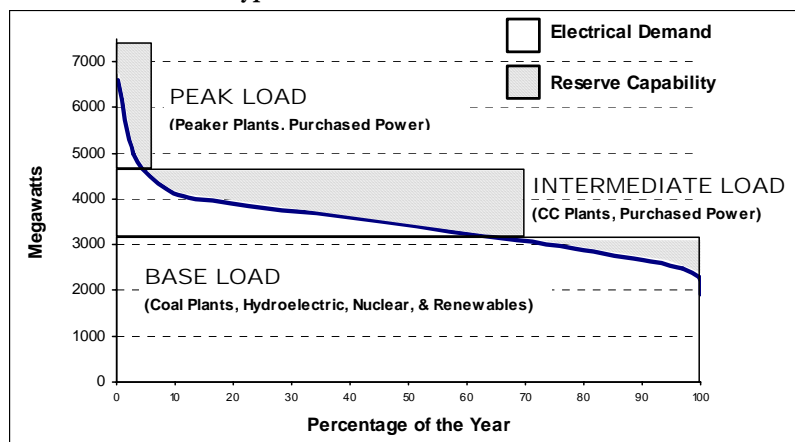
Energy is the total amount of electricity that consumers use over time and is measured in watt-hours (Wh). Similar to kW and MW, 1,000 Wh equals a kilowatt-hour (kWh) and one-thousand kWh equals a megawatt-hour (MWh). A kWh is equal to the energy of 1,000 watts working for one hour. The average American consumes approximately 12 kWh of energy each day or 4,241 kWh per year.

Electrical demand is broken down into base load, intermediate load, and peak load in order to determine the type and quantity of power plants needed to satisfy a particular demand. Different types of plants using different fuels or combination of fuels fulfill one or more of these three types of demand. The demand and supply conditions surrounding the summer peak load (i.e., high air conditioning load) usually drives the need for increased electrical generation. **Reserve capability** is the generation above the annual energy requirement. The remaining energy capability is necessary to ensure that annual load need is met economically.

The three boxes in Figure 2 represent the power provided by a utility's power plants and purchases over the course of a year. The utility's electrical demand varies from a base load of approximately 3,000 megawatts (MW) to a peak load of over 6,000 MW. The power not used, or demanded, would be ready in reserve.

Base load plants provide a base level of electricity to the system and are typically large generating units. Historically, nuclear energy or coal has powered base load plants in Wisconsin. These plants often require a substantial financial investment to build (higher construction cost), but are less expensive to operate over longer periods of time. Base load plants operate almost continuously (70 to 80 percent of the time) except when down for scheduled maintenance, repairs, or unplanned outages. They take a long time to "ramp" back up to full capacity and have limited to no ability to vary their output of electricity.

Figure 2 Electrical Plant Capacities and Types of Load Demand in a Year



In contrast, plants that satisfy peak load demand provide the additional power needed during peak system demand periods. Peak load plants (peaker plants) are highly responsive to changes in electrical demand. They can be turned off and on relatively quickly and can vary the quantity of their electrical output by the minute. They usually operate only 10 to 15 percent of the time. Peaker plants are relatively expensive to operate but cost less to build than base load or intermediate load plants. Peaker plants are most often natural gas combustion turbine plants.

The cost and flexibility of intermediate load plants falls in between base and peak load plants. They are constructed specifically for cyclic operation. They normally operate during times of elevated load demand, between 30 and 60 percent of the time. Compared to peaker plants, they are generally more efficient and therefore, cost less to operate, but are more expensive to build.

Existing Power Generation in Wisconsin

Maintaining reliable and economical electrical generation for the state of Wisconsin depends on a sufficient quantity of the right types of power plants operating in a cost-effective manner. A diversity of energy resources also helps achieve stability of generation and prevents dependence upon a specific fuel.

Currently, 85 percent of the state's electric capacity is composed of plants that burn fossil fuels (coal, natural gas, oil) and fossil fuel-burning plants produce almost 75 percent of the electricity actually used. Among the types of fossil fuels, the overwhelming majority of the state's electric capacity is from the combustion of coal. More than 70 percent of the electricity actually used in Wisconsin is generated from coal-burning plants. The difference between capacity and electricity used is more clearly visible by examining the role of peaker plants in the state. Approximately 30 percent of Wisconsin plant's non-coal capacity is provided by natural gas-burning peaker plants.

However, they actually produce less than 5 percent of Wisconsin's total electricity because they operate only during peak demand periods.

From 1970 to 2000, coal use in Wisconsin's power plants increased by more than 230 percent. Coal is one of the cheapest fuels available and will most likely continue to provide the bulk of Wisconsin's generation in the foreseeable future. However, more natural gas power plants are being proposed in Wisconsin because the combustion of natural gas is environmentally cleaner and more economical than oil on a kilowatt-hour basis.

Nuclear power plants produce over 20 percent of Wisconsin's electricity and can generate 1,510 MW of energy. These plants were built between 1970 and 1974 and have federal licenses to continue operating until 2010 and 2013.

Electrical power can also be produced from sources such as hydropower, wind, and other renewable resources. Approximately 5 percent of Wisconsin's energy demand is met by renewable resources. They are discussed later in this overview.

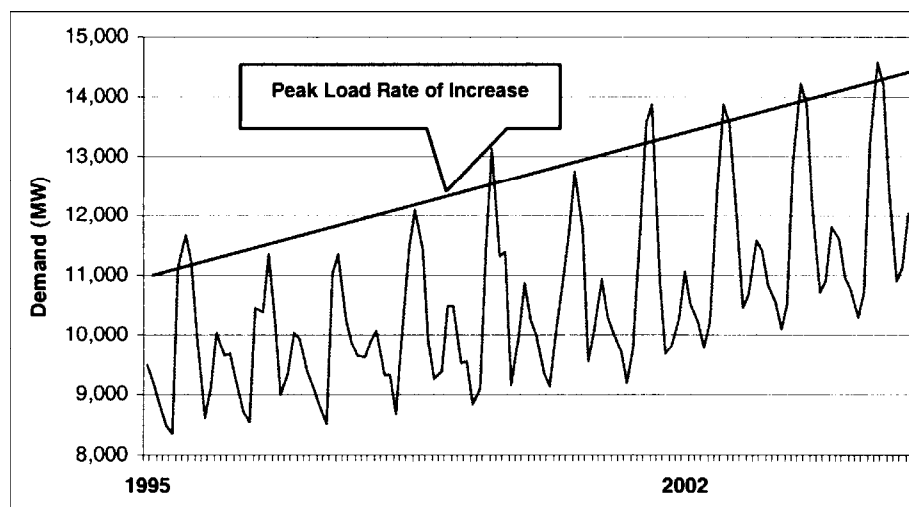
Need for New Power Plants in Wisconsin

Wisconsin has reached a point where new power generation must be considered. In 2002, Wisconsin had 170 electricity generation sites. The majority of this generation is concentrated in 31 large generating plants (plants with capacities over 100 MW). These larger plants comprise 75 percent of the state's capacity.

The bulk of Wisconsin's electric generation is produced by plants that are more than 25 years old. The average date of construction for the 31 large generating plants is 1978. Some of Wisconsin's plants are over 40 years old. No base load power plant has been built in Wisconsin since 1985. Older power plants may be inefficient, more costly to operate, and produce more environmental wastes than newer plants using newer technologies. They can be modified to increase their life span, increase electrical output, make use of different fuels, reduce environmental impacts, or they may be retired. If plants are retired, new plants must be built to satisfy the state's growing demand for electricity.

From 1990 to 2000, Wisconsin's population increased nearly 1 percent per year; but electric demand increased approximately 2 percent per year. Total electric demand in Wisconsin is increasing about 200 to 250 MW per year. This increase in electricity usage is a result of new customers, business growth, increased consumer consumption, and extreme weather conditions. Figure 3 shows the seasonal fluctuations in electrical demand from 1995 to 2001, with projections thru 2004. Figure 3 illustrates the peaks of demand that occur during the summer months and the reduced demand that occurs during the remainder of the year. In Wisconsin, the monthly peak demands have increased in proportion with the increase in total electric demand.

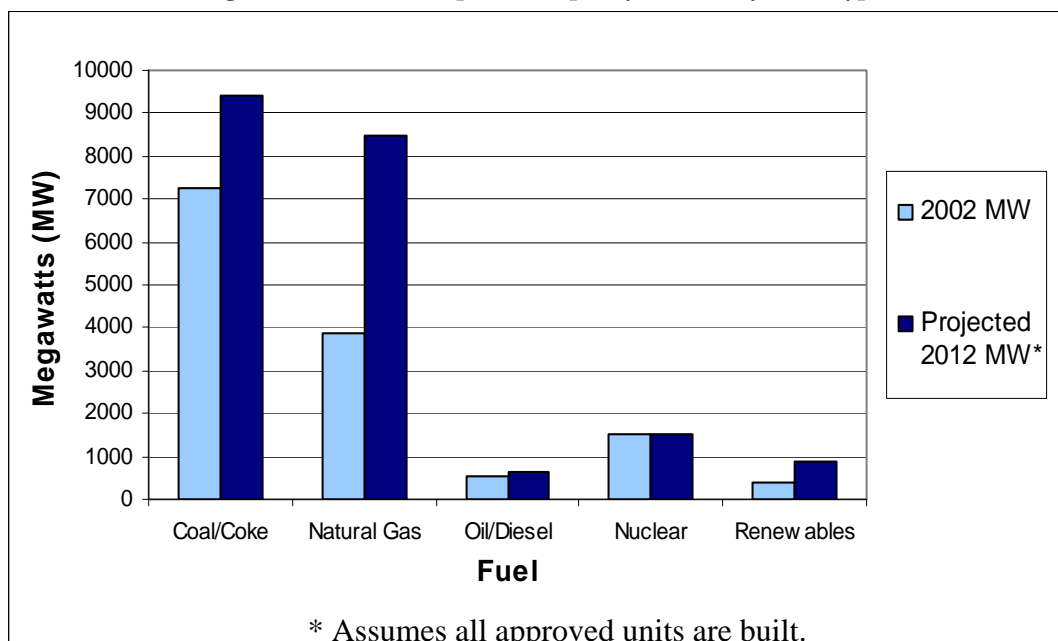
Figure 3 Increase in Wisconsin's Monthly Peak Load Demand
Actual Data 1995-2001; projected data 2002-2004



Retail electricity providers expect summer peak demands to increase 560 MW annually. Growth in electric demand must be met either by importing electricity or building new power generation plants.

Figure 4 shows the expected change in Wisconsin's generated electricity by fuel type from 2002 to 2011.

Figure 4 Wisconsin Expected Capacity Growth by Fuel Type



Common Types of Power Plants

Different power plant fuels, technologies, and combinations of the two are used to generate electricity to meet specific load demands. Each technology and fuel has attributes that are both positive and negative. The majority of Wisconsin's electricity is generated through the use of coal combustion, natural gas combustion, and nuclear energy. Technologies that redirect waste products for additional energy generation or other work such as combined-cycle (CC) or cogeneration plants, produce less environmental emissions and are often more efficient or cost-effective.

In the majority of power plants, electricity is generated by transforming chemical energy in the fuel into mechanical energy which turns a rotary engine or turbine. The turbine drives an electric generator that produces electricity.

Coal as Fuel

Coal power plants produce electricity by burning pulverized coal mixed with extremely hot air. The resulting high-pressure steam turns a turbine which drives an electric generator that produces electricity. Coal plants have high construction costs, but relatively low fuel costs. In 2002, coal energy costs averaged \$1.26 per million British thermal units (MBtu). Coal plants are base-load plants because they generate electricity continually, except during maintenance and repairs. The design capacity of coal plants can range from small to very large (over 600 MW).

Although coal is inexpensive, burning coal releases significant levels of sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon dioxide (CO₂), particulate matter (PM), and mercury into the air. Environmental concerns surrounding the use of coal to produce energy include global warming, acid rain, regional and local health issues, and the impacts of coal transport and ash disposal. The goal of newer coal combustion technologies has been to reduce the environmental impacts. In addition to the air emissions, most coal plants have significant community impacts due to the transport and handling of the coal (roads, trains, and barges), the need for a sizeable workforce, and a requirement for large quantities of cooling water.

Natural Gas as Fuel

Natural gas also can be burned in a boiler to heat water for steam which turns a steam turbine to generate electricity. Many former coal plants have been converted to use natural gas. In the recent past, natural gas costs (\$4.26 per MBtu) have been significantly higher than other fuel costs. In addition, the price of natural gas is volatile which can lead to increased electricity prices for consumers. The burning of natural gas releases fewer air emissions than coal. Compared to similarly sized coal plants, natural gas plants release 50 percent less CO₂. The greatest emissions are NO_x emissions which can be minimized with various control technologies.

There are two main natural gas power plant types.

Combustion turbine plant

Combustion turbine (CT) plants typically burn natural gas. CTs burn fuel and compressed air to create a very hot gas. The hot gas turns a turbine connected to a generator which produces electricity. CTs have relatively low construction costs but are more expensive to operate. Their efficiency is typically low, approximately 28 percent. Because of these traits, CTs are commonly constructed as peak load plants and used only during periods of peak demand such as in the summer, when cooling appliances require high amounts of energy very quickly. Air emissions of CTs include NO_x, CO, and CO₂.

Combined-cycle plant

Combined-cycle (CC) power plants include CTs as part of the overall technology. However, a CC plant is more efficient than a CT because the hot rejected heat gases of the CT are not vented to the atmosphere, but are used to produce steam for a second electric generator. By combining the gas and steam cycles, CC power plants convert approximately 40 percent of the fuel energy into electrical energy. Construction and operating costs are between those of coal plants and those of CTs. CC power is commonly used to run intermediate load plants, operating more hours than a peaking plant. CC plants also produce less NO_x and CO₂ emissions than a CT plant.

Nuclear Power

Nuclear plants are fueled by the splitting of uranium atoms under high temperatures. The dividing atoms create heated water and steam which turn a turbine that drives an electric generator. Like most coal plants, they are used to satisfy base load demand because they operate continuously. Nuclear plants are expensive to build but are the most inexpensive source of electricity overall (less than \$0.50 cents per MBtu). The capacity of Wisconsin's nuclear plants range from 498 to 507 MW.

Air emissions are not an issue with nuclear plants. The main concern is safety involving the storage and management of highly radioactive spent nuclear fuel. At this time, no new nuclear plants may be built in Wisconsin. (Wis. Stat. § 196.493) The Commission cannot issue a Certificate of Public Convenience and Necessity (CPCN) for a new nuclear plant until a federally licensed facility is built with adequate capacity to dispose of the high-level nuclear waste from all the nuclear power plants operating in Wisconsin. Currently, the Federal Department of Energy is in the process of preparing an application to obtain a Nuclear Regulatory Commission (NRC) license to proceed with construction of a long-term repository at Yucca Mountain in Nevada.

As a temporary alternative, the NRC has authorized the use of on-site, dry cask storage of spent fuel. Fuel removed from the reactor is placed in a pool of water to remove the heat from the fuel. The spent fuel pools at Wisconsin's nuclear facilities were sized to store spent fuel for only five to seven years, at which point the new fuel was to be shipped off-site to a long-term repository. Dry casks are built to store spent fuel that can be removed from the spent fuel pools in the plants. The casks are stored on a special pad out-of-doors. The casks would hold fuel until the long-term repository was available. It is currently anticipated that a federal high-level nuclear waste repository may open in 2010.

Power Plants Using Renewable and Recycled Resources

Renewable resources generate electricity without using conventional fuels such as coal, natural gas, oil, and uranium. Renewable resource generation plants can be small and dispersed throughout the electric system or can be large and centralized. They can burn renewable fuels or avoid combustion altogether. Four types of renewable energy plants are described below.

Hydroelectric Power

Hydroelectric plants use falling water to turn a turbine that drives a generator to produce electricity. Sizes range from large, utility-owned dams on major rivers to small locally-owned dams on small streams. Hydroelectric power plants have high construction costs, but are long-lived with very low energy costs. Plant capacity can range from a few kW to hundreds of MW. They operate typically as base load units because they run continuously. Small hydropower plants exist along the Wisconsin, Chippewa, Flambeau, and Wolf Rivers, among others. This renewable resource appears fully developed at this time.

Hydroelectric power plants produce no air emissions. Their main environmental impacts are related to the flooding of the landscape upstream, changing flows within the stream banks downstream, dividing the stream into separated pools, and damaging or killing young fish. The barriers created by dams constrain fish and other species to specific pools, impacting their ability to survive and reproduce. The turbines have the potential to damage or kill young fish if they are not filtered aside on the upstream side of the dam.

Wind Power

Wind energy is converted to electricity when wind passes by blades designed like those of an airplane propeller mounted on a rotating shaft. As the wind moves the blades, the rotation of the shaft turns a generator which produces electricity. Three factors affect wind machine power, the length and design of the blades, the density of the air, and the wind velocity. Longer blades produce more power output. Cold air is denser, which means it has more force, or ability to turn the blades (approximately 20 percent more). In general, as elevations increase, wind turbines will encounter greater wind velocities.

Current wind plant sizes range from small-scale wind machines (50 kW) to large-scale “wind farms” (30 MW). The typical maximum capacity of individual turbines is approximately 1.5MW. Wind power has low operating costs but high construction costs. Turbines operate approximately 90 percent of the time, but have an effective capacity factor of only 20 percent. Wind power is not affected by fuel prices, but is dependent on constant high wind speeds. Without constant winds, predictable power generation is an issue with wind generation. Wind power has low environmental impacts (no air or water emissions), but concerns have been raised over aesthetics, noise, and mortality to flying birds.

Solar - Photovoltaic Power

Photovoltaic (PV) cells convert sunlight directly into electricity. PV panels, consisting of multiple PV cells can be used in small groups on rooftops or as part of a system for producing large amounts of electrical power. The amount of energy produced by a PV system depends upon the amount of sunlight available. The intensity of sunlight varies by season of the year, time of day, and the degree of cloudiness. Use of solar power in Wisconsin may be limited by our relatively large number of overcast days.

Currently, PV-generated power is less expensive than conventional power technologies where the load is small or the area is too difficult to serve by electric utilities. The initial construction costs of solar power may be very high, but the production costs are very low. The total cost is about 30 to 40 cents per kWh. Recent technological breakthroughs may further reduce this cost. Compared to traditional methods of electric generation, solar power has few environmental concerns. The primary impacts for larger systems are related to land use and aesthetics and may be resolved through appropriate siting.

Biomass Power

Biomass power plants burn recently-grown plant materials, or residue and biological waste as opposed to “fossil” fuels. Solid biomass can be burned like coal to produce steam. It can also be gasified and burned like natural gas. More common biomass fuels include waste wood, and dedicated crops. Biogas also is a form of biomass, consisting of methane and other combustible gases that can be used in a conventional engine or gas turbine to turn an electric generator. Biogas can be generated from on-farm anaerobic digestion, landfill gas collection, and wastewater treatment plants.

Air emissions from biomass combustion are generally less than those from coal or natural gas. Like coal or natural gas combustion, biomass combustion produces CO₂, an important greenhouse gas. Biomass can also emit lower

amounts of NO_x, produce less ash than coal, and release significantly less toxic material such as mercury. A closed methane digestion system that burns biogas on a farm or landfill would reduce the amount of methane lost to the atmosphere (methane is a greenhouse gas). However, it would release emission similar to those released by natural gas-fired CT or CC facilities, but in smaller quantities. Environmental impacts vary with the type of biomass fuel used, although most fuels will have impacts related to transport (truck or rail) and storage. Biomass technologies are continuing to improve.

The Role of the PSC

The PSC has primary authority over most power plant construction. The PSC is a state agency comprised of staff and three commissioners. The three commissioners act as a decision-making body. The PSC determines whether or not projects can be built, where they should be built, and under what conditions. Construction of any power plant greater than 100 MW requires a CPCN from the PSC. Utility projects 100 MW or less requires a Certificate of Authority (CA). The Department of Natural Resources (DNR) is responsible for issuing permits and approvals for air emissions, dredging, water discharges, and waste disposal. DNR reviews the application for impacts to wetlands, rivers, protected habitats, and threatened/endangered species. Other state and federal agencies are responsible for enforcing additional regulations.

The PSC considers many aspects of a power plant application. These considerations include the cost and need for the proposed plants, its location, its community and environmental impacts, and a review of project alternatives. More details of this process are included in the Power Plant Siting Criteria and the Electric Power Plants Approval Process brochures. Public involvement is solicited in the form of meetings, hearings, and public comment periods. For larger projects, an environmental impact statement (EIS) is prepared by the PSC or jointly with the DNR. The public's comments and testimony aid the Commission in making a decision and drafting an order that either approves, denies, or modifies the power plant application. The PSC has the authority to order additional environmental protections or mitigation measures.

The Strategic Energy Assessment

The Strategic Energy Assessment (SEA) is reported biennially by the PSC. It identifies new power plants and transmission projects that are planned to begin construction during the following three years. The SEA report is issued in July of even-numbered years. Copies of the SEA can be obtained by contacting the PSC. Some of the energy issues addressed in the SEA include:

- Adequacy and reliability of the state's current and future electric energy supply.
- Identification of new utility generation and transmission.
- Adequacy and reliability of purchased generation capacity and energy.
- Adequacy of transmission transfer capability.
- Projected demand for electric energy.
- Identification of activities to discourage inefficient and excessive power use.
- Identification of existing and planned facilities that produce energy using renewable resources.
- Economic development, public health and safety, environmental protection, and diversification of supply.
- Adequacy of the regional bulk-power market.
- Contribution of competition to low-cost electricity.

Contact for further information:

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